auspices of the Society of Dyers and Colourists, and a further investigation on the nitration of oils has been begun, and under the research scheme of the Institution of Electrical Engineers work is now being done concerning insulating oils. The study of the chlorination products of rubber, one of which, known as "duroprene," is remarkable for its resistant and other properties, has been taken up. Research on fuels has included: heating by gas, the stripping of coal-gas, the distillation of cannel and other coals, as well as exhaustive examinations on certain products obtained from coal-mines, and also upon a series of seams of Lancashire coal. The conditions of carbonisation of iron, especially in case-hardening; the influence of impurities on the strength and on the resistance to corrosion of cast-iron; the influence of sulphur in the processes for making malleable iron castings, and on the toughening of copper and increasing the strength of copper alloys, have all been the subject of investigation and experiment with valuable results which have found industrial applications, whilst research on cellulose subsidised by the Department of Scientific and Industrial Research has also been in progress.

In the department of printing and photographic technology investigations were carried out, and are still proceeding, on the development of machine-printed photogravure, and much attention has been paid to new methods for the production of lithographic printing surfaces in monochrome and colour.

Much other research has been carried out or is in progress on the economic use of fuel, on air pollution, on gas flames, on the economic use of electricity for heating purposes, on fibre testing, and on the use of ramie waste for gas-mantles.

All the departments of the college have throughout the period of the war been busily engaged on investigations in aid of the requirements of the several departments of the Government. The results of some of the researches engaged in are shown in the space allotted to the college at the exhibition. It is to be hoped that the exhibition so happily inaugurated in London will serve to convince the public that British science intelligently applied can, if we so will it, contend successfully with the best efforts of the most highly educated of foreign nations.

THE CONCEPTION OF THE CHEMICAL ELEMENT AS ENLARGED BY THE STUDY OF RADIO-ACTIVE CHANGE.[1]

IF a chemist were to purify lead from silver, and found on re-examining the lead that silver were present, and if, again and again, silver, initially absent, reappeared the doctrine of the unchangeability of the elements would be at an end. The conclusion in 1902 by Sir Ernest Rutherford and myself with regard to the element thorium was of this direct and simple character. As often as the constituents responsible for the radio-activity are separated by physical or chemical means, they reform. One of the constituents, the thorium emanation, is a gas which was shown to possess the complete absence of chemical character characteristic of the argon family of gases. It is formed from thorium through the intermediary of another constituent, thorium-X, which is left in the filtrate, when a solution of thorium is precipitated by ammonia, but not by other chemical reagents. In turn the emanation changes into non-volatile products causing the active deposit. The clear conception of the nature of chemical change, the distinction between atoms and molecules, which we owe to the founders of chemistry, made it possible to recognise radio-active change almost instantly as a case of spontaneous transmutation. Novel as the explanation was, the phenomena explained are so novel as to transcend what to a generation ago would have appeared as the limits of the physically possible. But even to-day it is only in radio-active phenomena that the limits reached long ago in the chemical analysis of matter have been overstepped, and the rubicon, which many have vaulted over so lightly in imagination, has actually been crossed by science.

The first phase of the study of radio-active change was mainly concerned with the disentanglement of the long and involved sequence of transformations which, starting from uranium and thorium, were ultimately found to include all the known radio-elements. Beyond the fact that the radio-elements were in present course of evolution, it added little to the conceptions of chemistry. But in the second and more recent phase—concerned with the chemical character of the successive products, the law connecting this with the type of ray expelled in the change, the discovery of elements with unique radio-active but identical chemical and spectroscopic character, the identification of these as isotopes, or elements occupying the same place in the periodic table, the interpretation of the latter and the recognition that the so-called chemical elements are in reality heterotopes, or substances occupying different places in the periodic table, and are not necessarily even homogeneous—conclusions, not merely novel, but upsetting, have been reached.

The criterion at first relied upon in the analysis of matter into its elements, the possession of a unique chemical character, was added to by Dalton's atomic theory, which gave to each element a unique atomic weight. The periodic law apparently connected these two criteria, fitted the individual elements into families, and showed that, whatever the elements were, they were all of a class, the limits of chemical analysis, and, if complex, then all of the same kind of complexity. The periodic law introduced a third criterion of the element, that it occupied a place to itself in this scheme, and the discovery of spectrum analysis, a fourth, that it possessed a unique spectrum. The discovery of radio-activity introduced a fifth, the possession of a unique radio-active character, in the case of the radio-elements. Of the first three new elements discovered by the aid of the fifth criterion, polonium, actinium, and radium, the claim of the last to the title of element was brilliantly substantiated by the successive determination of its unique spectrum, unique chemical character, unique place in the periodic table, and unique atomic weight. The production of this element from uranium through the intermediary of ionium, and the production of helium from radium, and, in due course, from the other radio-elements, furnished conclusive proofs of the correctness of the first interpretation of the transmutational character of radio-active change.

Then came a totally new departure. The possession of unique radio-active character does not always, as in the case of radium, connote unique chemical and spectroscopic character. As, one after another, the various members of the disintegration series were distinguished, by their breaking up in characteristic ways at definite rates, no further *chemically new* elements were found. All resembled known elements so closely that they could not be separated by chemical analysis, and those actually at work on these substances came to the conclusion that the chemical resemblances amount to identity. Radio-thorium is, for example, identical chemically with thorium. It was isolated from thorium and individually recognised by Sir William Ramsay and O. Hahn only because it is formed from thorium through an intermediate product, mesothorium, chemically different from thorium, but chemically identical with radium. No more elegant addition, not merely to knowledge, but also to the means of winning knowledge, can be imagined. Two separate substances, radio-thorium and thorium, in the original analysis of the thorium disintegration series, taken for one, become individually knowable, because the first is formed from the second through a third substance chemically totally distinct from either. Radio-active change thus furnished a new means of analysis, for which, outside the radio-elements, there is as yet no equivalent.

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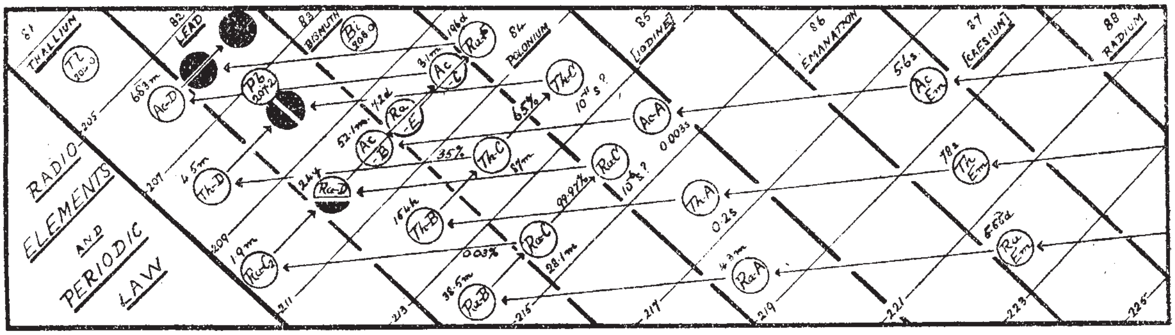
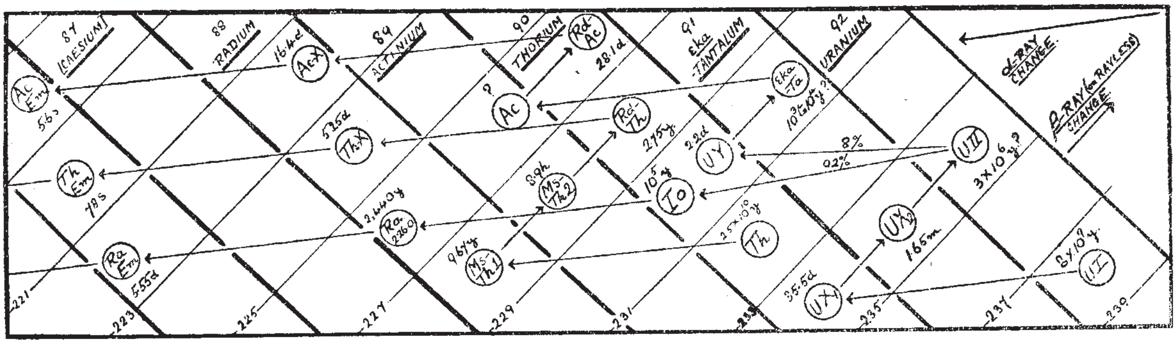
[1] Summary of a lecture delivered to the Chemical Society, December 19, 1918, by Prof. Frederick Soddy, F.R.S.

Further work on the chemical character of the various members of the disintegration series, notably by Fleck, who showed that practically all were chemically identical either with some common element or other radio-element, in 1913 paved the way for the generalisation independently arrived at by Russell, Fajans, and myself, which is brought up to date and illustrated by the accompanying figure. Each α-ray change was found to cause a shift of two places in the periodic table in one direction, and each β-ray change a shift of one place in the other, the first change being accompanied by a reduction of four units of atomic mass, a helium atom being expelled, and the second not involving a sensible loss of mass. Thus the successive places in the periodic table were first associated with unit variation of atomic charge, for the β-particle is the negative electron, and the α-particle a helium atom carrying two positive atomic charges. The elements with identical chemical character were found to occupy the same place in the periodic table, and were, therefore, termed isotopes. Conversely, the elements recognised by chemical and spectroscopic analysis may be termed heterotopes.





In the figure, which is to be read at 45°, the numbers at the head of each place—92 for uranium, and so on—are the atomic numbers, or number of the place in the complete list of places in the periodic table, as determined by Moseley, on the assumption that the atomic number of aluminium, the thirteenth element in the list, starting from hydrogen, is 13. The period of average life of each member is shown above or below its symbol, a "?" indicating that the period is indirectly estimated from the range of the α-ray expelled. The last member to be added, eka-tantalum or proto-actinium, the direct parent of actinium in an α-ray change, was discovered this year independently by Cranston and myself, and by Hahn and Meitner. For this element, for actinium, and for polonium, but for none of the others, are the criteria of unique spectrum and chemical character, as found for radium, to be expected. Moreover, the period of eka-tantalum, as estimated from the range of its α-rays by Hahn and Meitner, makes it appear that in due course determination not only of the spectrum, but also of the atomic weight and complete chemical nature, of this element will be possible. It is only in this way that the open question whether the actinium series branches off as shown at uranium-II or at uranium-I can be settled.

As the figure shows, so far as the changes have been followed, they all result in the production of isotopes of lead ranging in atomic weight from 206 to 210, the main products being that of uranium, 206, and both thorium products in the two branches, 208. The conclusion that lead was the ultimate product of thorium was new, but the prediction that the ultimate products of both uranium and thorium are different isotopes of lead—the one with an atomic weight less, and the other with an atomic weight greater, than that of common lead, 207·2—has been completely confirmed by experiment, and it has also been shown that ionium has an atomic weight lower than thorium (compare NATURE, July 19 and 26, 1917).

The older chemical analysis of matter distinguished only heterobaric heterotopes. The newer methods depending on radio-active change distinguish, not only heterobaric, but isobaric isotopes, and also isobaric heterotopes—that is, substances of different atomic weight and identical chemical character, of the same atomic weight and chemical character, and of the same atomic weight and different chemical character. A glance at the chart will show many examples of all three kinds. Not only has the chemical element been robbed of its time-honoured title to be considered the ultimate unchanging constituent of matter, but its title to be considered homogeneous has also vanished. The century that began with Dalton and ended with the discoveries of Becquerel and the Curies took the practical conception of the element it found extant, as that which could not be further resolved, and made of it the central conception of a theory of the ultimate constitution of matter. The element was first atomised, and then the atom and the element became synonyms, related as the singular is to the plural. Every one of the conceptions which associated the atom with the chemical element now has to be modified. Atoms of different chemical elements may have the same atomic weight; those of what the chemist and spectroscopist regard as the same element may have different atomic weight; and, most difficult to include of all to anyone to-day attempting to define the chemical element, even though the atoms all have the same weight, the element, nevertheless, may be an unresolvable mixture of fundamentally different isobaric isotopes. Present-day complete identity may conceal differences for the future of paramount importance, if ever transmutation is practically realisable at will. The goal that inspires the search for the homogeneous constituents out of which the material world is composed is now known to be, like infinity, approachable rather than attainable. The practical and necessary conception of the chemical elements, as understood before these discoveries, is, of course, unaffected. It had, and it has, a real significance as representing the limits of the spectroscopic and chemical analysis of matter, which remains, though it is now known to convey something very unlike the original and natural conception of the elements as the *l m n*'s of the material alphabet.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE following candidates have been elected to represent University constituencies in the House of Commons (members of the late Parliament are distinguished by an asterisk):—*Oxford:* *Lord Hugh Cecil and *Mr. R. E Prothero. *Cambridge:* *Mr. J. E. P. Rawlinson and *Sir Joseph Larmor. *London:* *Sir Philip Magnus. *Combined English Universities:* *Mr. H. A. L. Fisher and Sir Martin Conway. *Wales:* *Mr. J. Herbert Lewis. *Scotland:* *Sir Watson Cheyne, Mr. D. M. Cowan, and *Sir Henry Craik. *Dublin:* *Mr. A. W. Samuels and Sir Robert Woods. *National:* Mr. J. MacNeil. *Queen's (Belfast):* Sir William Whitla.

THE National Education Association, Caxton House, Westminster, has prepared and published a useful summary of sixteen quarto pages (price 6*d.*) of the Education Act, 1918, in which the Act is succinctly summarised and explained. The pamphlet further contains a brief *résumé* of each of the sections of the Act, in which is included only the operative words and phrases grouped under special headings, such as the "Organisation of Education," "Co-operation and Combination," "Expenditure," "Attendance at Continuation Schools," "To Aid Research," "Central Schools and Classes," "Education Grants," etc. It will prove exceedingly helpful to members of education committees, to officials engaged in administration, and to the teaching profession, both public and private, since it gives without technical and legal verbiage a clear view of the operations of the Act, and enables them to see how very much of the Act can, even in present circumstances, be brought into immediate operation. Now that the war is practically over it may be assumed that the Board of Education, as it is empowered by the Act, will, so soon as the conditions of peace are arranged and the treaty is signed, bring into operation the vital sub-sections of the Act raising the compulsory age of attendance at public elementary schools to fourteen years in all areas, and empower local authorities to raise by by-law the age to fifteen where so desired. Already a majority of the sections of the Act is in full operation, and it only awaits the conclusion of peace for this, the most important Act of the last session of Parliament, to come into full and salutary effect.

IT has been known for some time that, by reason of the general interruption of academic studies during the war, special and temporary provision would be made for the admission of men of military age into the Civil Service otherwise than by competitive examination. Announcement is now made that appointments within the scope of clause 5 of the Principal Order (the Civil Service (Consolidating) Order, January 10, 1910) may be made by selection on a competitive basis, but without competitive examination, through the agency of a selection board or boards appointed by the Treasury, and according to regulations framed, or to be from time to time framed, by the Commissioners, and approved by the Treasury. All men who have served either in his Majesty's Naval, Military, or Air Forces, or, being unfit for general service in those forces, have been employed in one or more of his Majesty's Civil Departments during the war, and are in a position to satisfy the Commissioners and the Selection Board that they are of the requisite age, health, character, and educational and other qualifications, will be eligible to compete for such appointments. It is understood that the Selection Board to be appointed by the Treasury will be charged with the work for India and the Colonies, as well as for the Home Service. It is very important that these Selection Boards shall include representatives of scientific and other modern subjects, as well as those with literary or legal interests, so as to ensure that a just proportion of the candidates appointed shall possess the training and knowledge which a progressive nation needs in its administrative officials.

IN the *Scientific Monthly* for September Prof. George Sarton has an article on "The Teaching of the History of Science," which gives further insight into his ideas on this subject. Just as a skilled workman employed day by day on the one job he can do best runs the risk of becoming a human machine, so the scientific investigator who devotes his life to one particular field of research is in danger of losing touch with reality. The workman may gain a broader outlook over the work on which he is engaged by attending evening classes at a technical institute; for the scientific investigator Prof. Sarton recommends lectures on the history of science. The lecturers on this subject would give comprehensive surveys of the whole field of science, illustrating their lectures, so far as possible, with models and simple experiments. The author considers that each university should establish three such courses:—(*a*) An introductory course on the history of science throughout the ages; (*b*) the history of a particular science; and (*c*) the history of science and civilisation at a special period. The two special courses would be changed from year